MICROCONTROLLER FOR MECHATRONIC SYSTEMS
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Abstract: The paper deals with microcontrollers, which are as the brain of the mechatronic products. Microcontroller is able to obtain signals from sensors or other devices and it is able to controll actuators or send information to other microcontroller.

1   Introduction

Microcontrollers are belonging to group of embedded systems, which are applicable for control of processes and product functions. This purpose needs to capture information about the product and also about surround. These information's have to be processed inside the microcontroller and after processing the microcontroller makes decision about next steps if it is necessary. Right decision depends on suitable selected sensors and processing of captured information. Data capturing and processing is the main role of microcontroller. Microcontroller also communicates with user or another microcontroller or any different kind of embedded system (fig. 1).
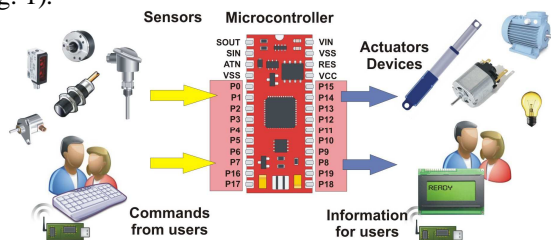

Figure 1 Role of the microcontroller in mechatronic systems

The product with embedded microcontroller behaves as intelligent systems. If it is necessary it could be as autonomous user less system. Behavior of such systems is subjected to user, which has possibility to affect to product processes. Products with embedded systems also could has another hidden additional functions as self-testing, self-

monitoring, emergency function mode for crisis situations, self-repairing etc. These functions help to overcome various unexpected situations. Very often these products have the user guide function and help to users handling with this product. The paper is focused to data capturing via using the microcontroller [1-5].

2   TTL logic levels

Almost every computer works with binary coded signals. It means that everything is expressed with logical level one "1" and logical zeros "0". Digital electronics rely on binary logic to store, process, and transmit data or information. Binary Logic refers to one of two states – ON or OFF. This is commonly translated as a binary 1 or binary 0. A binary 1 is also referred to as a HIGH signal and a binary 0 is referred to as a LOW signal.

The simplest way is using of two state sensor, which has on output only logical zero or one. A majority of microcontroller systems we use rely on 5 V TTL Logic Levels. Transistor–transistor logic (TTL) is a class of digital circuits built from bipolar junction transistors (BJT) and resistors. It is called transistor–transistor logic because both the logic gating function (e.g., AND) and the amplifying function are performed by transistors (contrast with RTL and DTL).

For any logic family, there are a number of threshold voltage levels to know. The minimum output HIGH voltage is 2.5 V. Basically, this means that output voltage of the device driving HIGH will always be at least 2.5 V. The minimum input HIGH voltage is 2 V, or basically any

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voltage that is at least 2 V will be read in as a logic 1 (HIGH) to a TTL device. Likewise, the maximum output LOW voltage is 0.4 V. This means that a device trying to send out a logic 0 will always be below 0.4 V. The maximum input LOW voltage is 0.8 V. So, any input signal that is below 0.8 V will still be considered a logic 0 (LOW) when read into the device.

3   Switch (two state) sensors

Sensors convert measured variables into electrical signals (fig. 2). Nowadays, many sensors converts the signal into digital form at the point of measurement. Some sensors have simple two-state output (yes-no; "0" – "1") indicating the state of measured quantity, e.g. temperature detector, water level detector, smoke detector etc. Very frequently this type of sensors works as switch from electric viewpoint. In this case it is possible to connect these sensors directly to microcontroller input pin. This can be done by adding a pull-up resistor (to +5V), or a pull-down resistor (resistor to ground) on the input. A 20K resistor is a good value for a pull-up or pull-down resistor.
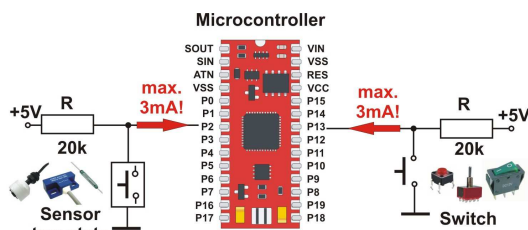

Figure 2 Switch sensors connected to microcontroller

4   Resistive sensors

Big group of sensors available on market are sensors with resistive output. The strategy for interfacing resistive sensors is generally to include them in a resistive voltage divider. This converts the resistance to a varying voltage. The voltage is then read with an Analog to Digital Converter (ADC). Very often microcontroller includes the ADC converter on specific pins. If there is no ADC pin on microcontroller, it is possible to use simple voltage divider adjusted to working between logical levels HIGH/LOW (fig. 3).
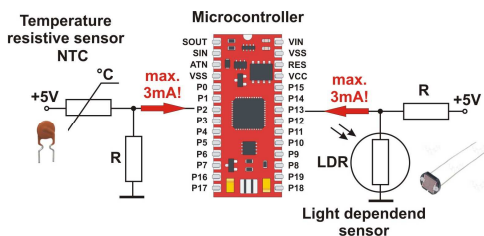

Figure 3 Resistive sensors connected to microcontroller

5   Sensors with pulse output

Microcontroller works with HIGH and LOW logical levels, so it is no problem to measure frequency modulated or pulse modulated signal from sensor like PWM (pulse width modulation) signal from accelerometer or encoder signal for measurement of rotation angle and velocity etc. Almost every microcontroller has built in counter/timer for reading and generating of pulse signal (fig. 4). PWM signal is very frequently used for controlling of DC motor speed.
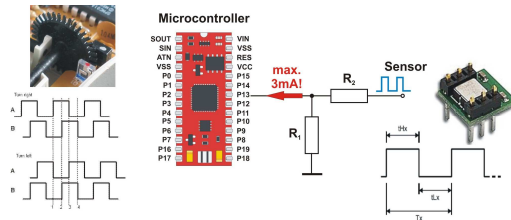

Figure 4 Pulse sensors connected to microcontroller

6   Controlling of power systems

Embedded system realized through the microcontroller includes signal processor. It means that it operates with low voltage and low currents, which are safely for the controller. The maximum current is limited to several milliampers. Direct connection most of actuators to pin of microcontroller causes the immediately damaging of pin al overall microcontroller.

This problem can be solved via using of high power part as transistor, thyristor, triac, relay etc. Inductive loads (DC and AC motors etc.) require big attention in selecting of power parts and circuits. Protection diode is very often used for this purpose (fig. 5).
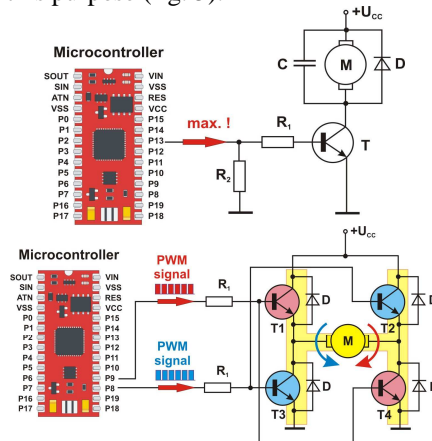

Figure 5 Microcontroller with power transistor and protection diode for inductive load and H-bridge for DC motor control

7   Controlling of RC servos

RC servo is positional servomechanism, which consists of DC motor, positional sensor and control electronic. There are rotational and also linear servos. Controlling of these servos is with conventional RC signal. It is pulse-width modulation signal and width of pulse constitutes the value of desired position of angular horn or linear shaft. Pulse width is in range from 1ms to 2 ms and delay between the pulses is in range from 10ms to 20ms (fig. 6). Pulse with width of 1ms means that rotation servo horn rotates to position -90° and pulse with width of 2ms means horn

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rotation to position +90° (fig. 6). Linear servo shaft is moving out to end position for pulse width of 1 ms and pulse with width of 2 ms causes the forward shifting of the linear servo shaft (fig. 6).
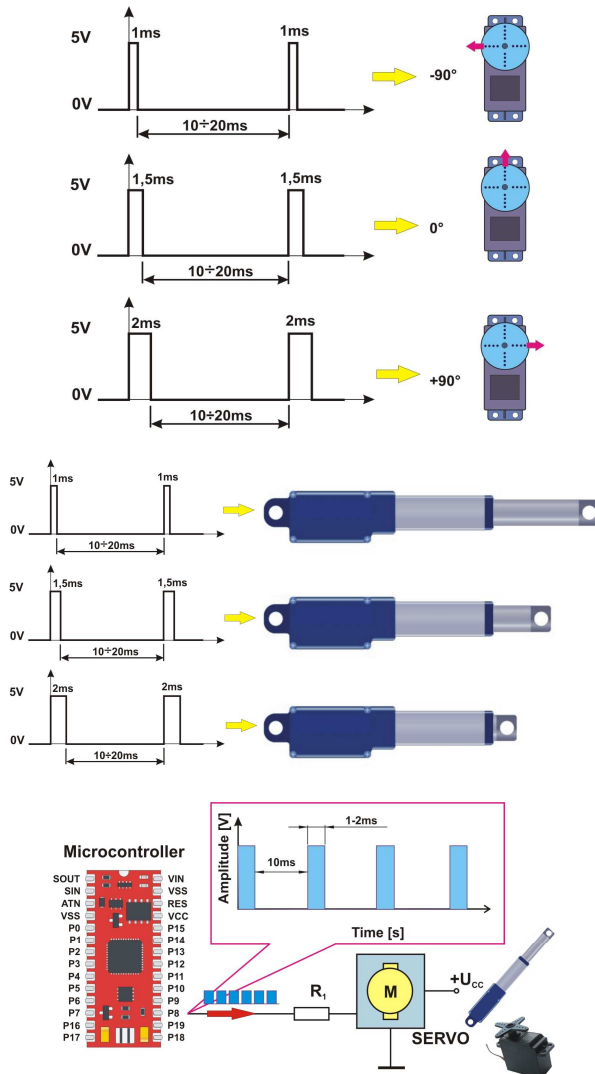

A unipolar stepper motor has one winding with center tap per phase. Each section (A, B, C, D) of windings is switched on for each direction of magnetic field. Since in this arrangement a magnetic pole can be reversed without switching the direction of current, the commutation circuit can be made very simple (e.g., a single transistor) for each winding (fig. 7).
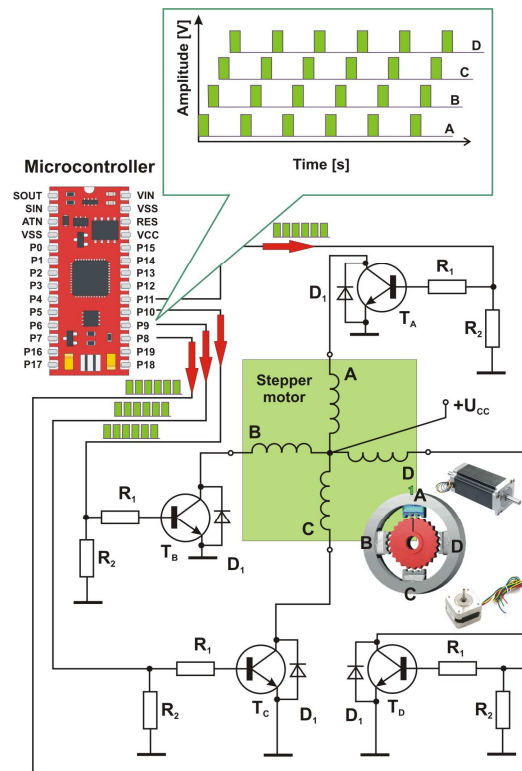

Figure 7 Controlling of the unipolar stepper motor

Abilities of microcontroller is limited to several input-output pins, limited amount of memory, limited instructions per second, limited simultaneously running processes etc. That is the reason of making the groups of microcontroller (fig. 8).
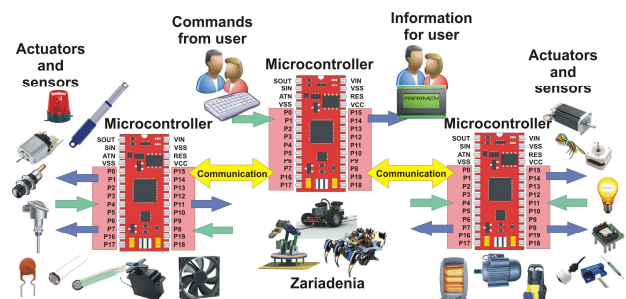

Figure 6 Principle of rotational servo and linear servo and connecting to microcontroller

8   Controlling of stepper motor

Stepping motor is a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor's position can then be commanded to move and hold at one of these steps without any feedback sensor (an open-loop controller), as long as the motor is carefully sized to the application in respect to torque and speed.

The stepper motor is known by its property to convert a train of input pulses (typically square wave pulses) into a precisely defined increment in the shaft position. Each pulse moves the shaft through a fixed angle.

There are two basic winding arrangements for the electromagnetic coils in a two phase stepper motor: bipolar and unipolar.

Figure 8 Multi-core embedded systems

All activities can be divided between these microcontrollers and system is faster than with one microcontroller. Also it is possible to make redundancy system with increased safety. It means that it is possible to

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develop product with self-testing, self-diagnostic, self-repairing, reconfigurable system, multitasking in real time and other activities which are too many for one microcontroller. This is reason why microcontrollers are grouped together in one product.

Main task is to compose the communication between microcontrollers for fast executing of processes. Safety communication is the first mainly in product, where human life is taking into account. Standard serial or parallel communication is used in multi-core embedded systems between microcontrollers. Serial communication is frequently used, but parallel communication takes many pins and wires and it is used only for some of LCD displays.

Many serial communication systems were originally designed to transfer data over relatively large distances through some sort of data cable. The term "serial" most often refers to the RS232 port on the back of the original IBM PC, often called as serial port.

Many variations of serial communications are used for microcontrollers: RS-232 (probably the most ubiquitous of all serial ports), RS-485, RS-422, UniversalSerialBus (USB), I2C (also IIC, InterIntegratedCircuit) Bus, Ethernet, PS2, FireWire IEEE 1394, CAN bus, SPI etc.

Holder if information is logical levels "0" and "1", which can be realized for every type with different values of voltage. Microcontrollers frequently use TTL logic at all pins and some of the pins use also inverted logic RS-232 and I2C logic (fig. 9).
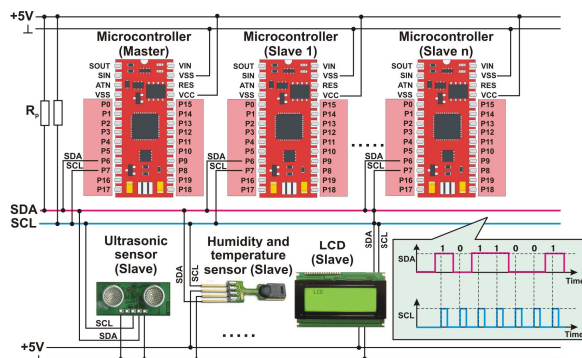
Figure 9 I2C communication in multi-core embedded systems

Other possibility is communication through the 1-Wire® bus also known as MicroLAN™ (fig. 10). It was defined by Dallas Semiconductor company as communication bus between electrical devices. It uses the same logical levels as TTL logic. The topology of this bus consists of only one data wire and common ground [6].

This bus allows the half-duplex both side communications. The specific property is that data wire can be used also as power supply for connected devices. This bus allows connecting up to 1500 devices into only one-wire bus [6].
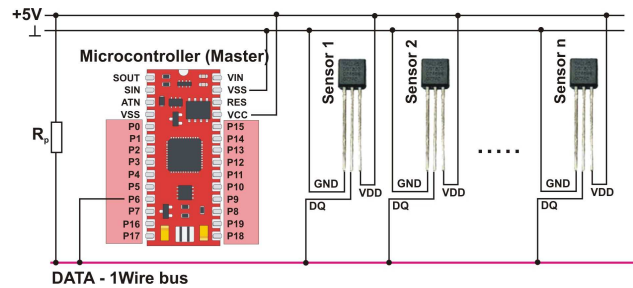
Figure 10 1Wire communication in multi-core embedded systems

9   Conclusion

More sophisticated didactic models are also used in educational process. Students design flowcharts for realization of specified functions and after that can write source code for programming of microcontroller.

Lift model as complex model (fig. 11) has been developed. Several master thesis and bachelor thesis have been defended on partial problems of this topic.

Line follower LINA 2010 (fig. 12) didactic model is developed for competition between students. Every student works on own algorithm and trains on this robot. After optimalization and completing of program students can compete. The main goal of competition is to follow line but also obstacle avoiding of brick is necessary. Line follower LINA 2010 also has to pass through the bridge and through the tunnel with door. Door is opened only when robot moves switching cube at minimum of 2 cm in any direction. The winner is who is the most quickly.
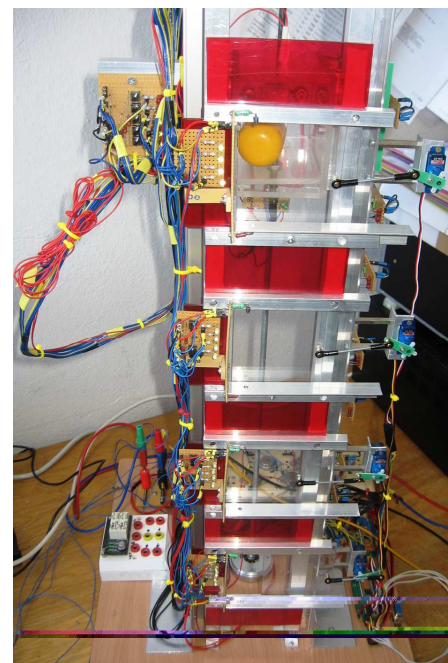
Figure 11 Didactic model of the lift

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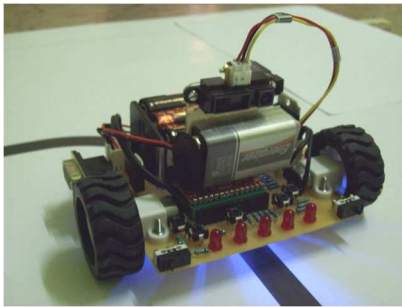Ivan Virgala; Ľubica Miková; Michal Kelemen; Tomáš Lipták; Darina Hroncová

Figure 12 Didactic model of linefollower robot

Automotive industry is perfect place for using of embedded systems. The first electronic pieces were used to control engine functions and were referred to as engine control units (ECU). As electronic controls began to be used for more automotive applications, the acronym ECU took on the more general meaning of "electronic control unit", and then specific ECU's were developed. Now, ECU's are modular. Two types include engine control modules (ECM) or transmission control modules (TCM). A modern car may have up to 100 ECU's and a commercial vehicle up to 40. Car has many independent functions and automotive electronics or automotive embedded systems are distributed multi-core systems, and according to different domains in the automotive field, they can be classified into: engine electronics, transmission electronics, chassis electronics, active safety, driver assistance, passenger comfort, entertainment systems etc [1, 2].

Finally the automotive industry is still under the development and result of embedded systems including is the driver-less cars. [3-19].

Acknowledgement

References
[1] ACAR, M., and PARKIN, R.M.: Engineering Education for Mechatronics, *IEEE Trans. on Industrial Electronics*, vol. 43, no. 1, pp. 106-112, Feb. 1996.

[2] CASTLES, R. T., ZEPHIRIN, T., LOHANI, V. K., KACHROO, P.: Design and Implementation of a Mechatronics Learning Module in a Large First-Semester Engineering Course, *IEEE Trans. on Education*, vol. 53, no. 3, pp. 445-454, Aug. 2010.

[3] OSTOJIC, G., STANKOVSKI, S., TARJAN, L., SENK, I. and JOVANOVIC, V.: Development and Implementation of Didactic Sets in Mechatronics and Industrial Engineering Courses, *Int. J. of Eng. Education*, vol. 26, no. 1, Tempus publications, 2010.

[4] BRADLEY, D.: What is Mechatronics and Why Teach It?, *Int. J. of Electrical Eng. Education*, 41, (2004), pp. 275-291, 2004

[5] BRADLEY, D.: Mechatronics - More questions than answers, *Mechatronics*, vol. 20, no. 8, Special Issue on Theories and Methodologies for Mechatronics Design, pp. 827-841, Dec. 2010.

[6] VITKO, A., JURIŠICA, L., BABINEC, A., DUCHOŇ, F., KĽÚČIK, M.: *Some Didactic Problems of Teaching Robotics*, Proceedings of the 1st International Conference Robotics in Education 2010. Bratislava, 16.-17. 9. 2010, Bratislava, Slovak University of Technology in Bratislava, ISBN 978-80-227-3353-3, pp. 27-30, 2010.

[7 KONIAR, D., HARGAS, L., SIMONOVA, A. et al.: *Virtual Instrumentation for Visual Inspection in Mechatronic Applications*, 6th Conference on Modelling of Mechanical and Mechatronic Systems (MMaMS) Location: Vysoke Tatry, SLOVAKIA Date: NOV 25-27, 2014.

[8] van BEEK, T. J., ERDENA M. S., TOMIYAMAA, T.: Modular design of mechatronic systems with function modeling, *Mechatronics*, vol. 20, no. 8, pp. 850-863, Dec. 2010.

[9] WANG, Y., YUA, Y., XIEA, Ch., WANGA, H., FENG, X.: Mechatronics education at CDHAW of Tongji University: Laboratory guidelines, framework, implementations and improvements, *Mechatronics*, vol. 19, no. 8, pp. 1346–1352, Dec. 2009.

[10] KELEMEN, M., KELEMENOVÁ T. and JEZNÝ, J.,: Four legged robot with feedback control of legs motion. In: *Bulletin of Applied Mechanics*. Vol. 4, no. 16, p. 115-118, 2008.

[11] VIRGALA, I., VACKOVÁ, M., KELEMEN, M.: Two-legs walking robot "Wirgil". In: *Medical and treatment*. Vol. 40, no. 2, p. 32-35, 2010.

[12] MIKOVÁ, Ľ., KELEMEN, M., KELEMENOVÁ, T.: Four wheeled inspection robot with differential controlling of wheels. In: Acta Mechanica Slovaca. Vol. 12, No. 3-B, p. 548-558, 2008.

[13] DUCHOŇ, F., HUBINSKÝ, P., HANZEL, J., BABINEC, A., TÖLGYESSY, M.: Intelligent Vehicles as the Robotic Applications, *Procedia Engineering*, Volume 48, p. 105–114. 2012.

[14] KONIAR, D., HARGAŠ, L., ŠTOFAN, S.: Segmentation of Motion Regions for Biomechanical Systems, *Procedia Engineering*, Volume 48, p.304–311. 2012.

[15] BOŽEK, P., CHMELÍKOVÁ, G.: *Virtual Technology Utilization in Teaching*, Conference ICL2011, September 21 -23, 2011 Piešt'any, Slovakia, pp. 409-413. 2011.

[16] TURYGIN, Y., BOŽEK, P.: Mechatronic systems maintenance and repair management system. *Transfer of innovations*, 26/2013. pp. 3-5. 2013.

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[17] HARGAŠ, L, HRIANKA, M, KONIAR, D, IZÁK, P.: *Quality Assessment SMT Technology by Virtual Instrumentation.* Applied Electronics 2007, 2007.

[18] SPANIKOVA, G., SPANIK, P., FRIVALDSKY, M. et al.: Electric model of liver tissue for investigation of electrosurgical impacts, *Electrical Engineering*, Volume: 99, Issue: 4, pp. 1185-1194, 2017.

[19] KARAVAEV, Y. L., KILIN, A. A.: Nonholonomic dynamics and control of a spherical robot with an internal omniwheel platform: Theory and experiments, *Proceedings of the Steklov Institute of Mathematics*, Volume 295, Issue 1, 1 November 2016, Pages 158-167, 2016.

[19] Kuric, I., Bulej, V., Saga, M., Pokorný, P., *Development of simulation software for mobile robot path planning within multilayer map system based on metric and topological maps*, International Journal of Advanced Robotic Systems, Volume: 14 Issue: 6, pp. 1-14, 2017.

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